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Operational ocean data assimilation/prediction system for the western North Pacific at JMA

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1. Introduction

Japan Meteorological Agency (JMA) has been routinely operating an ocean data assimilation and prediction system for the western North Pacific (MOVE/MRI.COM-WNP*) developed by the Meteorological Research Institute (JMA/MRI) since March 2008. The operational system assimilates the along-track sea level anomaly (SLA) data produced by Ssalto/Duacs and distributed by AVISO+, in addition to in situ temperature and salinity observations, and daily SST analysis (MGDSST).

* Multivariate Ocean Variational Estimation system / Meteorological Research Institute Community Ocean Model for the Western North Pacific, Usui et al. 2006

2. Outline of MOVE/MRI.COM-WNP system

Model

MRI Community Ocean Model (MRI.COM; Ishikawa et al., 2005)
- Primitive equations with free surface
- lat-lon coordinates and σ-z hybrid vertical coordinates
- region: 15°N-65°N, 117°E-160°W (Nested to North Pacific Model)
- resolution: 1/10°(lon.) x 1/10° (lat.) within 15°N-50°N, 117°E-160°E, 1/6° (lon.) east of 160°E and 1/6° (lat.) poleward of 50°N
  54 vertical levels from 0.5m at surface to 6000 m near the bottom
- Atmospheric forcing :
  [Analysis] 3-hourly data from Japanese 55-year Reanalysis (JRA-55; Kobayashi et al., 2015)
  [Forecast] daily data from control run of One-month Ensemble Prediction System of JMA
  * latent and sensible heat flux for both analysis and forecast are calculated from bulk formula of Kondo (1975) with model SST

Data Assimilation scheme

MOVE (Multivariate Ocean Variational Estimation system)
- Multivariate 3DVAR scheme with vertical coupled Temperature-Salinity (T-S) EOF modal decomposition (Fujii et al., 2003). Amplitudes of the T-S EOF modes are employed as control variables and the optimal temperature and salinity fields are represented by the linear combination of the EOF modes. The model domain is divided into 13 sub-regions (Fig. 1).
- Analysis is conducted every 5 days. Incremental Analysis Updates (IAU) technique is used to correct the model fields with the analysis result (Fig. 2).

Observation data (for operational system)
- In situ observations of temperature and salinity profiles (ship, buoy and ARGO float)
- Satellite altimetry data: Jason-2 along-track sea level anomaly (SLA) data from AVISO+, after adding them to the mean sea surface dynamic height (SSDH) calculated from a preliminary analysis using temperature and salinity observations alone.
- Sea surface temperature analysis (MGDSST: JMA-GHRSST product)

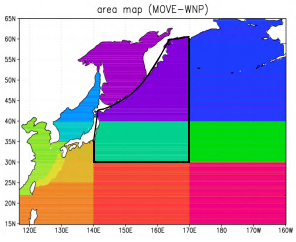

Fig. 1 Model region and sub-regions divided for EOF modes.

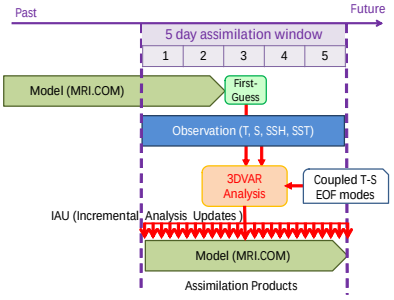

Fig. 2 System design of MOVE/MRI.COM-WNP system.

Analysis/Forecasting cycle (Operational system)
The execution date of delayed assimilation, defined as 'Base Date', is set every 5 days. The delayed assimilation is conducted on Base Date for the period from 54-day to 10-day before. Following the delayed assimilation, the 10-day near-real-time assimilation and 30-day prediction are conducted every day until the next Base Date.

Re-Analysis (Non-operational (1982-2013))
- Atmospheric forcing : JRA-55
- observation data :
  - in situ temperature and salinity measurements (GTS, WOD13, GTSPP)
  - satellite altimetry data : along-track sea level anomaly (SLA) data from AVISO+ (ERS-1/2, Topex/POSEIDON, Jason-1/2, ENVISAT, GFO, Cryosat-2, Saral/AltiKa).
  - MGDSST (Re-analysis : 1982-2006, Delayed analysis : 2007-2013)

3. Products

- Analysis data on ocean currents and several layers of subsurface water temperatures from 1985 are available on the NEAR-GOOS Regional Real Time Database for research users (Fig. 3, 4: http://ds.data.jma.go.jp/gmd/goos/data/database.html).
  - Region: the seas adjacent to Japan (15°N - 49°N, 117°E - 159°E, 0.1° x 0.1°).
  - Format: text (for data), gif (for map).
- The analysis and predicted data (temperature, salinity, sea surface height and velocity) are also available for commercial users through the Japan Meteorological Business Support Center.

Fig. 3 Top page of NEAR-GOOS Regional Real Time Database.

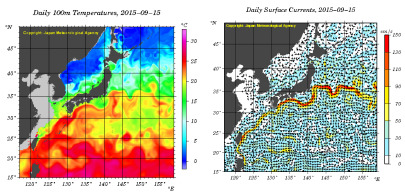

Fig. 4 Examples of NEAR-GOOS products.(Left: daily 100m temperatures. Right: daily surface currents.)

4. Performance of current forecasting

- Using MOVE/MRI.COM-WNP, JMA provides one month current/SST predictions over the seas around Japan. Especially, forecast of Kuroshio path is important for various marine industries and fisheries south of Japan.
- Figure 5 shows a recent current prediction for Kuroshio area (initial date is 29 Jun. 2015). This system was able to successfully forecast that the perturbation south of Japan would develop and the Kuroshio would take a meander path late July.

- Latest current prediction maps can be found in JMA-website (in Japanese explanation: http://www.data.jma.go.jp/gmd/kaiyou/data/db/kaikyo/ocean/forecast/predict.html)

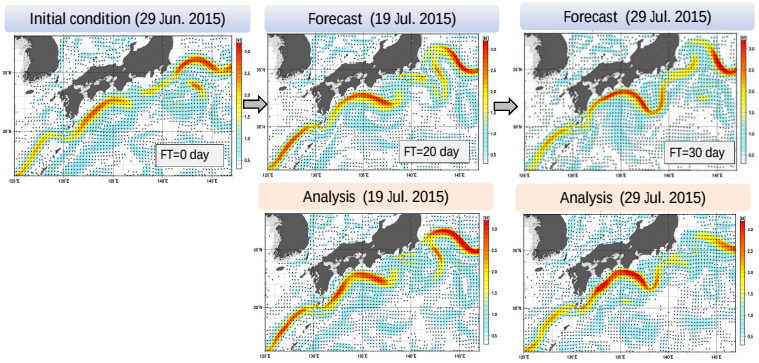

Fig.5. Time sequence of 50m-depth current field south of Japan. Arrows indicate only current direction (normalized by velocity) and shaded area denotes current speed. [Upper panels] Operational forecasting initialized at 29 Jun. 2015 with MOVE/MRI.COM-WNP. [Lower panels] Operational analysis.

5. Impact of multi-satellite altimeter SLA assimilation

JMA has a plan to introduce multi-satellite altimeter SLA data to the operational MOVE/MRI.COM–WNP system, which is now using only Jason-2 SLA data. To evaluate the impact of multi-satellite altimeter assimilation, two Observing System Experiments (OSE) are performed for the delayed mode analysis as listed below. (The evaluation for operational analysis is a future task.)

- Assimilated data (delayed along-track SLA data from AVISO+)
  Exp. Alt1: Jason-2 alone , Exp. Alt4: Jason-2, Cryosat-2, Saral/AltiKa and HY-2A
  (Both Exp. use in situ temperature and salinity data, and MGDSST)
- Calculation Period: 1 Jan. 2014 – 31 Dec. 2014

Results
- Figure. 6 shows RMSE of model SSH variations against those of 1/4 °x1/4 ° gridded absolute dynamic topography from AVISO+. RMSE in Exp.Alt4 is better than that of Exp.Alt1 around Kuroshio extension (KE) and south of 30N.
- Comparison with tide gauge data in Kuroshio area (Fig. 7) indicates good representation of SLA variations for both experiments, and slight improvement of correlation coefficient (0.77→0.84) for Exp.Alt4.
- Comparison with in situ temperature data (not independent) for KE area (Fig. 8) indicates little impact to the accuracy of temperatures. However, independent in situ profiles should be necessary for the precise validation.

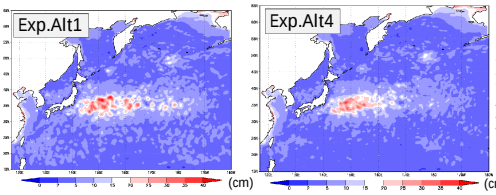

Fig.6 RMSE of model SSH variations against those of 1/4 ° x1/4 ° gridded absolute dynamic topography (delayed-time and 'all sat merged' version) from AVISO+, calculated for every 5 days from 4/Mar. to 24/Dec in 2014. To validate variational components, mean difference in both experiments are subtracted in the RMSE calculations.

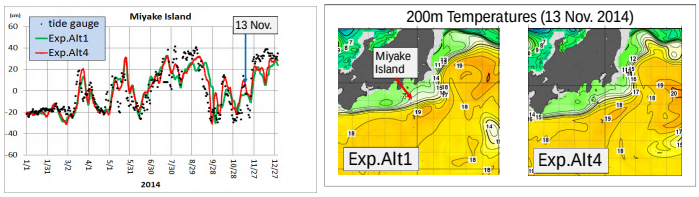

Fig.7 (left) Time series of SLA in tide gauge at Miyake Island and model SLA at the grid near Miyake Island. Tide gauge SLA are calculated by subtracting the tidal components and inverse barometer effects. Each data is adjusted so that the average in 2014 is zero for comparison. (right) 200m temperature maps around Miyake Island for 13 Nov. 2014 by Exp.Alt1 and Exp.Alt4.

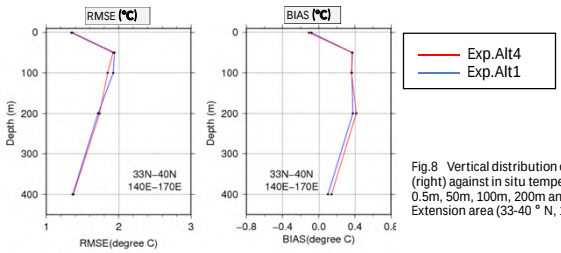

Fig.8 Vertical distribution of the RMSE (left) and bias (right) against in situ temperature data at depth of 0.5m, 50m, 100m, 200m and 400m for Kuroshio Extension area (33-40 ° N, 140-170 ° E).

References:

[1] Fujii et al., 2003: Three-dimensional analysis of temperature and salinity in the equatorial Pacific using avariational method with vertical coupled temperature–salinity EOF modes. *Journal of Geophysical Research: Oceans (1978–2012)* ,108(C9).
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